PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H01B 3/22 — A1

(11) International Publication Number: **WO 98/32137**

(43) International Publication Date: 23 July 1998 (23.07.98)

(21) International Application Number: PCT/DK98/00022

(22) International Filing Date: 19 January 1998 (19.01.98)

(30) Priority Data:
0059/97 17 January 1997 (17.01.97) DK

(71) Applicant *(for all designated States except US)*: NKT CABLES A/S [DK/DK]; NKT Allé 1, DK–2605 Brøndby (DK).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: PROCIDA, Inger, Margrethe [DK/DK]; Brønlunds Allé 46, DK–2900 Hellerup (DK). HANSEN, Bo, Svarrer [DK/DK]; Bolbro Villavej 8, DK–2960 Rungsted (DK).

(74) Agent: HOFMAN–BANG & BOUTARD, LEHMANN & REE A/S; Hans Bekkevolds Allé 7, DK–2900 Hellerup (DK).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.
In English translation (filed in Danish).

(54) Title: ELECTRIC CABLE

(57) Abstract

The present invention relates to an electric underwater cable comprising one or more conductors being surrounded by solid insulating material. The insulating material is impregnated with a dibenzyl toluene (DBT) oil. The cable is particularly suited for use at great and/or varying depths, as the cable is distinguished by a particularly good stability against pressure impacts and thermal variations.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	**ES**	Spain	**LS**	Lesotho	**SI**	Slovenia
AM	Armenia	**FI**	Finland	**LT**	Lithuania	**SK**	Slovakia
AT	Austria	**FR**	France	**LU**	Luxembourg	**SN**	Senegal
AU	Australia	**GA**	Gabon	**LV**	Latvia	**SZ**	Swaziland
AZ	Azerbaijan	**GB**	United Kingdom	**MC**	Monaco	**TD**	Chad
BA	Bosnia and Herzegovina	**GE**	Georgia	**MD**	Republic of Moldova	**TG**	Togo
BB	Barbados	**GH**	Ghana	**MG**	Madagascar	**TJ**	Tajikistan
BE	Belgium	**GN**	Guinea	**MK**	The former Yugoslav Republic of Macedonia	**TM**	Turkmenistan
BF	Burkina Faso	**GR**	Greece			**TR**	Turkey
BG	Bulgaria	**HU**	Hungary	**ML**	Mali	**TT**	Trinidad and Tobago
BJ	Benin	**IE**	Ireland	**MN**	Mongolia	**UA**	Ukraine
BR	Brazil	**IL**	Israel	**MR**	Mauritania	**UG**	Uganda
BY	Belarus	**IS**	Iceland	**MW**	Malawi	**US**	United States of America
CA	Canada	**IT**	Italy	**MX**	Mexico	**UZ**	Uzbekistan
CF	Central African Republic	**JP**	Japan	**NE**	Niger	**VN**	Viet Nam
CG	Congo	**KE**	Kenya	**NL**	Netherlands	**YU**	Yugoslavia
CH	Switzerland	**KG**	Kyrgyzstan	**NO**	Norway	**ZW**	Zimbabwe
CI	Côte d'Ivoire	**KP**	Democratic People's Republic of Korea	**NZ**	New Zealand		
CM	Cameroon			**PL**	Poland		
CN	China	**KR**	Republic of Korea	**PT**	Portugal		
CU	Cuba	**KZ**	Kazakstan	**RO**	Romania		
CZ	Czech Republic	**LC**	Saint Lucia	**RU**	Russian Federation		
DE	Germany	**LI**	Liechtenstein	**SD**	Sudan		
DK	Denmark	**LK**	Sri Lanka	**SE**	Sweden		
EE	Estonia	**LR**	Liberia	**SG**	Singapore		

Electric cable

The present invention relates to an electric cable for laying out under ground or under water. The invention in particular relates to an electric underwater cable which is particularly suited for laying out at great sea depths.

Electric cables, e.g. in the form of underwater cables, normally consist of one or more conductors which separately or together are surrounded by a solid insulating material being impregnated with a dielectric fluid, such as an oil. Such electric cables are normally designated O.F. cables (O.F. = oil filled).

Electric cables being buried under ground or in the form of underwater cables are normally very long and not readily accessible once they have been buried/laid out. Further, the cables are often exposed to thermal variations and high pressure impacts. The latter are in particular important in connection with underwater cables. Consequently, it is important that the cables have good stability towards these pressure impacts, and that the cable is capable of resisting these thermal variations to which they may be exposed in use, so that the cable may have a long service life without essential risk of leakage, rupture or compression of the cable.

DK patent specification No. 156 453 discloses an electric underwater cable of the above kind. The underwater cable disclosed therein is especially characterized in that 1-methyl naphthalene is used as dielectric fluid. 1-methyl naphthalene is suspected of being carcinogenic, and consequently it would be most unfortunate if such a cable were to spring a leak.

Leakage on such oil filled cables is very rare, but if it happens it is very important that the oil spilled is as little toxic as possible. The oils in the known O.F. cables described above do not meet this requirement, and it is thus expedient to find another oil for use in such cables, which oil is biodegradable and essentially harmless to micro-organisms in the ground or marine organisms.

It is the object of the present invention to devise an electric cable of the kind stated in the preamble, which at least has the same good properties as the cable disclosed in DK patent No. 156 453, and where the oil used is biodegradable and essentially harmless to micro-organisms in the ground and marine organisms in case of spillage of the oil.

It has now surprisingly turned out that an electric cable, such as an underwater cable comprising one or more conductors surrounded by a solid insulating material being impregnated with an insulating oil, where dibenzyl toluene (DBT) is used as oil, meets this requirement, as DBT surprisingly has turned out to be biodegradable, harmless to marine organisms, micro-organisms in the ground, and other biological organisms, and further DBT does not accumulate in the food chain. In addition, the DBT-oil is essentially insoluble in water, and in case of spillage from an underwater cable, the oil will sink to the sea floor from where, if desired, it may be removed by simple methods, e.g. suction.

As criterion for the choice of the oil which is disclosed in DK patent No. 156 453 it is i.a. mentioned that it is very essential that the oil has a sufficiently low viscosity at the temperatures of use for it to be able to follow cycles with expansion and contraction due to

thermal variations of the cable. Further, it is in particular necessary that the viscosity of the insulating oil must be sufficiently low for the oil, at any temperature to which the cable might be exposed, to be sufficiently flowable to be able to move along the cable and thereby constantly maintain the solid insulating material of the cable totally impregnated.

Other important criteria include that the oil must not have too high volatility. Further, the oil must possess good insulating properties, a low dielectric loss factor, and a good gas absorption capacity. The oil must not tend to separate solid paraffinic products at the lowest temperatures of use of the cable, and when used in underwater cables the oil must further have a density which is close to or equal to the density of the surrounding water.

The cable disclosed in DK patent No. 156 453 reasonably fulfils these criteria. If the cable is used at very great depths, and in particular at varying depths, there is, however, a certain tendency for the cable to get compressed so that the insulating property in these flattened areas is insufficient.

Thus, it is a further object of the present invention to devise an electric underwater cable of the kind stated in the preamble, which at least has the same good properties as the cable disclosed in DK patent No. 156 453, and which preferably has increased security against compression when used at great sea depths.

Thus, it has further turned out that an electric underwater cable comprising one or more conductors surrounded by solid insulating material being impregnated with an insulating oil, where dibenzyl toluene (DBT) is used as oil, has particularly good properties as compared with

the properties of the known underwater cables, in particular as regards the ability to resist local compressions.

Underwater cables and other oil-carrying cables according to the present invention thus comprise an insulating oil which preferably consists of pure dibenzyl toluene oil. The oil may, however, comprise minor amounts of impurities provided these impurities essentially do not change the flow properties and density of the dibenzyl toluene oil. In another embodiment, the oil comprises one or more of the alkylated hydrocarbons dibenzyl toluene, benzyl-methylbenzyl-benzene and ditolyl phenyl methane. The total amount of these other alkylated hydrocarbons preferably constitutes less than 20 weight-%, and in particular less than 10 weight-%.

The dibenzyl toluene oil can consist of one single isomer, but in view of viscosity and density it is preferred that the dibenzyl toluene oil is in the form of a mixture of two or more isomers. Such mixtures flow more easily in a cable, and thus the oil is even more able to follow cycles with expansion and contraction due to thermal variations of the cable, and to be able to move along the cable and thereby constantly maintain the solid insulating material of the cable totally impregnated. Further, it should be mentioned that such isomeric mixtures of dibenzyl toluene oil are significantly cheaper than pure isomers of this oil.

Table 1 shows some essential physical properties of insulating oils which have been used or contemplated for use in O.F. cables, and the corresponding properties for DBT. The physical properties for the naphthalene derivatives have been taken from Beilstein "HANDBUCH DER ORGANISCHEN CHEMIE" (Vierte Auflage).

TABLE 1

Oil	Melting point (°C)	Density at 20 °C (g/cm^3)	Viscosity at 20 °C (cSt)
1-methyl naphthalene	-30	1.020	3.5
1-ethyl naphthalene	-15	1.008	4.1
2-ethyl naphthalene	- 7	0.993	2.9
1-propyl naphthalene	-12	0.992	4.9
1-butyl naphthalene	-20	0.975	6.5
2-butyl naphthalene	- 5	0.970	4.75
2-tert.butyl naphthalene	- 4	0.970	-
1-pentyl naphthalene	-22	0.966	-
1,3-dimethyl naphthalene	- 4	1.006	-
1,6-dimethyl naphthalene	-14	1.003	-
1,2,3,4-tetrahydro naphthalene	-36	0.970	2.2
2-pentyl naphthalene	- 4	0.956	-
Dibenzyl toluene	-27	1.040	30.,0

As appears from the above table, the dibenzyl toluene oil has a particularly high viscosity as compared with the other oils, and further the dibenzyl toluene oil has a somewhat higher density and consequently also a density which is higher than the density of the surrounding water in which the cable is laid out.

Thus it is very surprising that electric underwater cables according to the invention have a significantly improved stability against pressure impacts and thermal variations as compared with known electric underwater cables with insulation comprising other of the oils mentioned in table 1.

In a particularly preferred embodiment of the invention, the electric cable comprises a solid insulating material in the form of cellulose. It is particularly preferred that the solid insulating material is in the form of paper wound round the conductor or conductors.

An electric cable according to the present invention may comprise one or more conductors having the same or different size. The number of and the diameter of conductors depend on how much power the cable is to conduct. It is particularly preferred that the cable according to the invention comprises one or more conductors which preferably each of them may have a diameter of up to about 5 cm.

The conductor or conductors may be formed from various materials, such as e.g. twisted copper or aluminium wires.

If the electric cable according to the present invention comprises two or more conductors it is preferred that the cable comprises at least one longitudinally progressing duct which essentially is filled with dibenzyl toluene. Hereby a more rapid and more easy distribution of the oil is obtained.

Underwater cables according to the present invention may advantageously be provided with an outer sheath in the form of a bendable sheath of e.g. plastic and/or metal being resistant to sea water.

In a first particularly preferred embodiment, the cable according to the invention comprises a centrally positioned conductor of an electrically conductive material, such as copper. The conductor is surrounded by a solid insulating material in the form of paper being wound round the conductor. The paper layer surrounding

the conductor has a thickness of preferably 1-5 cm and is impregnated with dibenzyl toluene oil. The cable further has a lead sheath and an outer sheath which optionally may be of polyethylene.

In a second preferred embodiment, the cable according to the invention comprises 2 or 3 conductors which each separate one is surrounded by a solid insulating material in the form of paper being wound round the conductor. The paper layer surrounding the conductor has a thickness of preferably 1-5 cm and is impregnated with dibenzyl toluene oil. The cable further has a common lead sheath and outer sheath which e.g. may be of polyethylene. Further, the cable is characterized by being flat, as the conductors, if there are more than 2, preferably are placed side by side. Furthermore, the cable is self-compensating.

EXAMPLES:

The effect of the DBT-oil on marine organisms was studied. Sceletonema costatum and Acartia tonsa were exposed to sea water saturated with 14-C labelled DBT (about 16 µm/l) and solutions thereof for 72 h and 48 h, respectively. The result of this experiment showed that the mortality (50% dead) of Sceletonema costatum and Acartia tonsa required a DBT concentration which is higher than the solubility of the oil in water.

The biodegradability of the DBT-oil was tested according to OECD guideline No. 306. The test results showed that the oil is biodegradable and is not accumulated in the food chain. The degradation of the DBT-oil will, because of methyl-bridges between the aromatic rings, not result in PAH-like molecules, but in smaller, increasingly more easily degradable molecules.

C l a i m s :

1. An electric cable comprising one or more conductors surrounded by solid insulating material being impregnated with an insulating oil, c h a r a c t e r i z e d in that the oil is pure dibenzyl toluene (DBT), dibenzyl toluene containing a minor amount of impurities, where the amount of impurities essentially does not change the viscosity and density of the dibenzyl toluene oil, or a mixture of dibenzyl toluene and one or more of the alkylated hydrocarbons dibenzyl toluene, benzyl-methylbenzyl-benzene and ditolyl phenyl methane, where the alkylated hydrocarbons preferably do not constitute more than up to 20 weight-% of the insulating oil.

2. An electric cable according to claim 1, c h a r a c t e r i z e d in that the cable is an underwater cable.

3. An electric cable according to claim 1 or 2, c h a r a c t e r i z e d in that the oil is a mixture of two or more isomers of dibenzyl toluene (DBT).

4. An electric cable according to claim 1, 2 or 3, c h a r a c t e r i z e d in that the solid insulating material is cellulose, preferably in the form of paper being wound round the conductor or conductors.

5. An electric cable according to any of the claims 1-4, c h a r a c t e r i z e d in that the cable comprises 1 or more conductors.

6. An electric cable according to any of the claims 1-5, c h a r a c t e r i z e d in that the cable comprises at least one longitudinally progressing duct which essentially is filled with insulating oil.

7. Use of dibenzyl toluene as insulating oil in electric cables, preferably in electric underwater cables.

8. Use of an electric cable comprising one or more conductors surrounded by solid insulating material being impregnated with an isolating oil selected from pure dibenzyl toluene (DBT), dibenzyl toluene containing a minor amount of impurities, where the amount of impurities essentially does not change the viscosity and density of the dibenzyl toluene oil, or a mixture of dibenzyl toluene and one or more of the alkylated hydrocarbons dibenzyl toluene, benzyl-methylbenzyl-benzene and ditolyl phenyl methane, where the alkylated hydrocarbons preferably do not constitute more than up to 20 weight-% of the insulating oil, for laying out on the sea floor.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/DK 98/00022

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H01B 3/22
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H01B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, CAPLUS, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0282083 A2 (NIPPON PETROCHEMICALS COMPANY, LIMITED), 14 Sept 1988 (14.09.88), page 4, line 22 - line 34, claims 1,6-7 --	1-8
A	File WPI, Derwent accession no. 96-458716, FUJIKURA LTD et al: "Oil filled power cable for underwater application - has insulating paper impregnated with mixture of hydrocarbon system insulation oil and alkyl diphenyl methane, which is wound to circumference of conductor part;" & JP,A,6302229, 941028, DW9646 --	1-8

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 April 1998	05 -05- 1998
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Sofia Nikolopoulou Telephone No. +46 8 782 25 00

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/DK 98/00022

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	File WPI, Derwent accession no. 93-081533, Nippon Petrochemicals Co Ltd: "Oil impregnated cable esp. submarine cable - comprises 1,1-di: phenyl:ethane and benzyl:toluene;" & JP,A,5028833, 930205, DW9310 --	1-8
A	US 4566994 A (HIROSHI HASEGAWA ET AL), 28 January 1986 (28.01.86), column 1, line 64 - column 2, line 5, claim 2 --	1,3-6
A	US 4225747 A (BERNARDINO VECELLIO), 30 Sept 1980 (30.09.80) -- --------	1-2,4-8

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/04/98

International application No.
PCT/DK 98/00022

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0282083 A2	14/09/88	SE 0282083 T3	
		DE 3850511 D,T	23/03/95
		JP 2022238 A	25/01/90
		JP 2022239 A	25/01/90
		JP 2063141 C	24/06/96
		JP 2063142 C	24/06/96
		JP 2514058 B	10/07/96
		JP 7088320 B	27/09/95
		JP 7088321 B	27/09/95
		JP 63314708 A	22/12/88
		US 4902841 A	20/02/90
		JP 2514024 B	10/07/96
		JP 63224110 A	19/09/88
US 4566994 A	28/01/86	DE 3320857 A,C	15/12/83
		FR 2528446 A,B	16/12/83
		GB 2124254 A,B	15/02/84
		JP 1683970 C	31/07/92
		JP 3049162 B	26/07/91
		JP 58216302 A	16/12/83
US 4225747 A	30/09/80	AR 218319 A	30/05/80
		AU 523884 B	19/08/82
		AU 3789378 A	17/01/80
		BR 7804740 A	17/04/79
		CA 1101088 A	12/05/81
		DE 2832861 A,C	08/02/79
		DK 156453 B,C	21/08/89
		DK 337178 A	30/01/79
		FR 2399100 A,B	23/02/79
		GB 1599745 A	07/10/81
		JP 1398067 C	07/09/87
		JP 54026484 A	28/02/79
		JP 61060521 B	22/12/86
		SE 444242 B,C	24/03/86
		SE 7806276 A	30/01/79